PROFESSOR W. R. NICHOLS

ON THE

BOSTON WATER SUPPLY.

[*From the Fourth Annual Report of the Boston Water Board, City Document No. 108, 1880.*]

To H. M. Wightman, Esq., *City Engineer:* —

Dear Sir, — I submit herewith in tabular form the results of such chemical examinations of Cochituate and Mystic water as have been made in my laboratory during the past year. The analytical work has been performed under my direction by Mr. W. W. Macfarlane, S.B., and I have full confidence in the accuracy of the results.

Cochituate Water.

The quality of the water delivered from the Cochituate works has been generally good. As in the case of all surface waters, a good filter will remove, at any time, more or less of animalcules and vegetable fragments, but there is no evidence that the presence of the small quantity of these foreign substances in the water actually used for drinking gives to it any unwholesome quality. During a portion of the year a very considerable amount of water has been contributed by the Sudbury-river works; and, as a result, at times the water as drawn in the city has been quite strongly colored. For a few days, during which, as I understood, experiments were being made on the flow of the water in the aqueduct, the water had rather a marked unpleasant taste, evidently due to the vegetable matter taken up in the storage basins. The beneficial effects of exposing a water of this character to the air, in an open conduit or by passing through a reservoir, are very marked.

Table I. contains the results of the examination of the water as drawn in the Laboratory of the Massachusetts Institute of Technology. The method employed is that known as Frankland's, some description of which was given in the last report of the Water Board. For the benefit of those to whom this method is yet unfamiliar, I may state that it consists in evaporating a certain quantity of the water to dryness, under suitable conditions, and subjecting the dry residue which remains to a process of organic analysis, in a closed vessel, in such a manner as to convert all the *carbon* and *nitrogen* of the organic matter into gaseous substances, which are collected and measured. The carbon and nitrogen are spoken of as *organic carbon* and *organic nitrogen* respectively, and they are sometimes taken together and spoken of as the *organic elements*. The method is difficult and tedious, requiring the use of expensive and frangible apparatus, and consuming considerable time; for these reasons it can never be popular. Moreover, as is the case with every method employed for obtaining indications of

the amount and character of the organic matter in the water, the results must be interpreted by a knowledge of the source from which the water is derived, and of its surroundings. It must be borne in mind, moreover, that the sum of the amounts of organic carbon and organic nitrogen does not represent the actual *amount of organic matter* present, for most organic substances which occur in natural waters contain in addition a larger or smaller amount of oxygen and of hydrogen; how much, in any particular case, we cannot tell. In interpreting the results it is felt that considerable importance attaches to the relative proportion of carbon to nitrogen, for it is, in general, true that organic matter of vegetable origin contains a larger proportion of carbon, while organic matter of animal origin contains a larger proportion of nitrogen.[1]

TABLE I. — *Examination of Boston Water.*

(Results expressed as so many parts by weight in 100,000 parts by weight of the water.)

Date.	Temperature in Centigrade Degrees.	Organic Carbon.	Organic Nitrogen.	Sum of the Organic Elements.	Ratio. $\frac{\text{Carbon}}{\text{Nitrogen.}}$
1879.					
June 26	. . . . .	0.386	0.022	0.408	17.5
July 2	. . . . .	0.377	0.026	0.403	14.5
" 9	. . . . .	0.376	0.030	0.406	12.5
" 23	22.1	0.384	0.048	0.432	8.0
" 31	23.2	0.339	0.029	0.368	11.7
Aug. 7	24.1	0.398	0.029	0.427	13.7
" 14	26.7	0.405	0.027	0.432	15.0
" 21	20.7	0.432	0.053	0.485	8.2
" 28	20.5	0.365	0.073	0.438	5.0
Sept. 4	20.3	0.401	0.063	0.464	6.4
" 11	20.1	0.436	0.042	0.478	10.4
" 18	19.5	0.443	0.072	0.515	6.1
" 25	17.9	0.444	0.069	0.513	6.4
Oct. 2	17.7	0.404	0.065	0.469	6.2
" 9	18.9	0.386	0.038	0.424	10.1
" 16	16.9	0.409	0.034	0.443	12.0
" 23	15.5	0.367	0.049	0.416	7.5
" 30	12.3	0.402	0.049	0.451	8.2
Nov. 21	8.8	0.407	0.062	0.469	6.6
Dec. 4	6.8	0.449	0.042	0.491	10.7
" 19	3.8	0.450	0.051	0.501	8.8

[1] For a fuller discussion of Frankland's method, see Report of Massachusetts State Board of Health, Lunacy and Charity, 1880. Department of Health, pp. 111, *et seq.*

TABLE I. — *Continued.*

Date.	Temperature in Centigrade Degrees.	Organic Carbon.	Organic Nitrogen.	Sum of the Organic Elements.	Ratio. $\frac{\text{Carbon}}{\text{Nitrogen.}}$
1880.					
Jan. 1	3.3	0.500	0.055	0.555	9.0
" 16	3.3	0.545	0.064	0.609	8.5
" 23	. . . . .	0.694	0.064	0.758	10.8
" 31	3.6	0.614	0.041	0.655	15.0
Feb. 5	2.9	0.659	0.061	0.720	10.8
" 9	4.0	0.668	0.072	0.740	9.3
" 12	. . . . .	0.723	0.063	0.786	11.5
" 19	3.0	0.592	0.051	0.643	11.6
" 25	3.1	0.526	0.064	0.590	8.2
Mar. 4	6.3	0.582	0.047	0.629	12.4
" 11	4.2	0.443	0.071	0.514	6.2
" 18	6.8	0.413	0.060	0.473	6.9
" 26	4.2	0.438	0.037	0.475	11.8
April 1	4.8	0.368	0.046	0.414	7.9
" 9	. . . . .	0.446	0.048	0.494	9.3
" 16	9.2	0.397	0.044	0.441	9.0
" 22	9.8	0.360	0.047	0.407	7.7
May 6	13.2	0.325	0.046	0.371	7.1
" 13	15.6	0.361	0.063	0.424	5.7
" 21	15.8	0.423	0.034	0.457	12.4
" 28	18.8	0.447	0.075	0.522	6.0
Mean of 42 samples	. . . . .	**0.452**	**0.051**	**0.503**	**8.9**

MYSTIC WATER.

The samples of Mystic water have been furnished me from the office in Charlestown. The results of the examination are presented in Table II., together with the record of the examination of samples taken from the Mystic pond itself during a portion of the year. These samples were taken two feet below the surface, at a point some distance from the shore where the water is usually about 75 feet deep.

TABLE II. — *Examination of Mystic Water.*

(Results expressed as so many parts by weight in 100,000 parts by weight of the water.)

Date.	Locality.	Organic Carbon.	Organic Nitrogen.	Sum of the Organic Elements.	Ratio. $\frac{\text{Carbon}}{\text{Nitrogen}}$	Ammonia.	"Albuminoid Ammonia."	Total Solids.
1879.								
June 19 . .	Charlestown . .	0.390	0.083	0.473	4.7	. .	. .	. .
" 26 . .	" . .	0.395	0.088	0.483	4.5	. .	. .	. .
July 3 . .	" . .	0.445	0.056	0.501	7.9	. .	. .	9.6
" 10 . .	" . .	0.762	0.100	0.862	7.6	. .	. .	10.0
" 17 . .	" . .	0.716	0.112	0.828	6.4	. .	. .	10.2
" 24 . .	" . .	. .	. .	. .	. .	0.004	0.033	10.5
" 31 . .	" . .	0.782	0.126	0.908	6.2	0.005	0.037	10.8
Aug. 7 . .	" . .	0.727	0.082	0.809	8.9	0.004	0.033	. .
" 14 . .	" . .	0.483	0.065	0.548	7.4	0.004	0.024	10.2
" 21 . .	" . .	0.400	0.107	0.507	3.7	0.005	0.024	10.4
" 28 . .	" . .	0.455	0.100	0.555	4.5	0.005	0.023	10.7
Sept. 4 . .	" . .	. .	. .	. .	. .	0.003	0.019	9.8
" 11 . .	" . .	0.407	0.112	0.519	3.6	0.004	0.021	9.5
" 18 . .	" . .	0.330	0.081	0.411	4.1	0.002	0.020	9.7
" 25 . .	" . .	0.352	0.062	0.414	5.7	0.004	0.020	9.6
Oct. 2 . .	" . .	0.364	0.059	0.423	6.2	0.004	0.016	9.8
" 9 . .	" . .	0.328	0.022	0.350	14.5	0.007	0.016	10.1
" 16 . .	" . .	0.315	0.021	0.336	15.0	0.001	0.013	9.6
" 18 . .	Mystic Pond . .	. .	. .	. .	. .	*0.001*	*0.016*	*9.7*
" 23 . .	Charlestown . .	0.316	0.055	0.371	5.7	0.003	0.013	9.7
" 30 . .	" . .	0.323	0.063	0.386	5.1	0.003	0.013	. .
Nov. 7 . .	" . .	0.301	0.056	0.357	5.4	0.005	0.013	10.0
" 8 . .	Mystic Pond . .	*0.307*	*0.057*	*0.364*	*5.4*	*0.007*	*0.012*	*9.6*
" 15 . .	" . .	*0.401*	*0.043*	*0.444*	*9.3*	*0.008*	*0.013*	*9.5*
" 20 . .	Charlestown . .	0.374	0.056	0.430	6.6	0.005	0.009	9.4
" 22 . .	Mystic Pond . .	*0.306*	*0.036*	*0.342*	*8.5*	*0.013*	*0.013*	*9.7*
Dec. 4 . .	Charlestown . .	0.275	0.022	0.297	12.5	0.009	0.011	9.9
" 8 . .	Mystic Pond . .	*0.269*	*0.043*	*0.312*	*6.3*	*0.011*	*0.013*	*9.2*
1880.								
Jan. 1 . .	Charlestown . .	0.315	0.046	0.361	6.8	0.012	0.013	9.9
" 15 . .	" . .	0.313	0.054	0.367	5.8	0.012	0.011	10.2
" 30 . .	Mystic Pond . .	*0.335*	*0.043*	*0.378*	*7.8*	*0.053*	*0.019*	*10.9*
Feb. 5 . .	Charlestown . .	0.375	0.066	0.441	5.7	0.025	0.018	11.0
" 6 . .	Mystic Pond . .	*0.401*	*0.095*	*0.496*	*4.0*	*0.040*	*0.023*	*11.4*

TABLE II. — *Continued.*

Date.	Locality.	Organic Carbon.	Organic Nitrogen.	Sum of the Organic Elements.	Ratio. $\frac{\text{Carbon}}{\text{Nitrogen}}$.	Ammonia.	"Albuminoid Ammonia."	Total Solids.
Feb. 12 . .	Charlestown . .	0.442	0.060	0.502	7.4	0.037	0.018	11.4
" 17 . .	Mystic Pond . .	*0.471*	*0.057*	*0.528*	*8.3*	*0.025*	*0.021*	*8.8*
" 19 . .	Charlestown . .	0.421	0.044	0.465	9.6	0.035	0.020	10.1
" 26 . .	" . .	0.346	0.039	0.385	8.9	0.031	0.016	10.4
March 4 . .	" . .	0.347	0.039	0.386	8.9	0.033	0.016	9.9
" 6 . .	Mystic Pond . .	*0.349*	*0.040*	*0.389*	*8.7*	*0.044*	*0.017*	*10.3*
" 11 . .	Charlestown . .	0.356	0.062	0.418	5.7	0.027	0.016	9.7
" 19 . .	" . .	0.314	0.060	0.374	5.3	0.027	0.013	9.9
" 25 . .	" . .	0.322	0.062	0.384	5.2	0.027	0.015	10.4
April 1 . .	" . .	0.309	0.045	0.354	6.9	. .	. .	10.3
" 5 . .	Mystic Pond . .	*0.273*	*0.046*	*0.319*	*5.9*	*0.040*	*0.016*	*10.1*
" 9 . .	Charlestown . .	0.297	0.044	0.341	6.8	0.024	0.015	10.7
" 14 . .	Mystic Pond . .	. .	. .	. .	. .	*0.041*	*0.017*	*10.2*
" 15 . .	Charlestown . .	0.361	0.054	0.415	6.7	0.020	0.017	10.5
" 22 . .	" . .	0.297	0.060	0.357	4.9	0.013	0.016	10.8
" 29 . .	" . .	. .	. .	. .	. .	. .	. .	10.4
May 3 . .	Mystic Pond . .	*0.386*	*0.061*	*0.447*	*6.3*	*0.037*	*0.020*	*10.2*
" 6 . .	Charlestown . .	0.256	0.054	0.310	4.7	0.007	0.017	10.7
" 12 . .	Mystic Pond . .	*0.366*	*0.082*	*0.448*	*4.4*	*0.031*	*0.021*	*10.5*
" 13 . .	Charlestown . .	0.333	0.068	0.401	4.9	0.008	0.016	10.9
" 20 . .	" . .	0.359	0.073	0.432	4.9	0.008	0.016	10.5
" 24 . .	Mystic Pond . .	*0.332*	*0.045*	*0.377*	*7.4*	*0.031*	*0.021*	*10.6*
" 27 . .	Charlestown . .	0.358	0.061	0.419	5.9	0.009	0.021	10.8
June, '79, to May, '80,	Charlestown Mean of 35–39 samples . .	0.392	0.065	0.457	6.0	0.012	0.018	9.9
Oct., '79, to May '80,	Mystic Pond (surface.) Mean of 12–14 samples . .	*0.349*	*0.054*	*0.403*	*6.5*	*0.028*	*0.018*	*10.0*
Oct., '79, to May, '80,	Charlestown Mean of 19–20 samples[1] . .	0.339	0.053	0.392	6.6	0.019	0.015	9.8

[1] This average is made up from the samples drawn in Charlestown during the time within which samples from the pond have also been examined.

In studying the figures in the foregoing table we see very clearly one fact to which I have frequently called attention, namely, the great variation to which surface-waters are subject, and especially in respect to the organic matter which they contain. On this account it is seldom possible to form a just idea of the general

character of such a water from a single examination. This variation is rendered very large in the present instance because, during the summer, there was in Mystic pond, and in the water as drawn in the city, a very large amount of certain microscopic plants belonging to the *algæ*, and similar to those which occurred in such quantities in Horn pond in 1876.[1] A full description of these plants, with a plate, occurs in the Report of the State Board of Health, Lunacy, and Charity, for 1880.

In order that the effect of their presence may appear more clearly, I have prepared Table III., in which we have the results presented, first in monthly averages, and then in averages for certain periods into which there seemed to be a natural division. The *algæ* became numerous enough to awaken complaint and apprehension after the middle of July, and the trouble was at its height in the latter part of July and during August.

TABLE III. — *Examination of Mystic Water.*

(Results expressed in parts in 100,000.)

Date.	Number of Samples.	Sum of the Organic Elements.	"Albuminoid Ammonia."
1879.			
June	Mean of 2 samples	0.478	
July	" " 4 "	0.775	0.035[1]
August	" " 4 "	0.605	0.026
September	" " 3 "	0.448	0.020
October	" " 5 "	0.333	0.014
November	" " 2 "	0.393	0.011
December	" " 1 "	0.297	0.011
1880.			
January	" " 2 "	0.364	0.012
February	" " 3 "	0.469	0.019
March	" " 4 "	0.390	0.015
April	" " 4 "	0.389	0.016[2]
May	" " 4 "	0.390	0.017
1879.			
June 19 — July 3	" " 3 "	0.486	
July 10 — Aug. 7	" " 4 "	0.852	0.034
Aug. 14 — Sept 11	" " 4 "	0.526	0.022
Sept. 18 — May 27, '80	" " 28 "	0.389	0.016

[1] Mean of two samples. [2] Mean of three samples.

[1] See First Annual Report of Boston Water Board, 1877.

Even in the absence of any abnormal condition such as was caused this summer by the growth of *algæ*, there is at times a considerable variation in the amount and character of the organic matter in the water, as, for instance, in October, 1879, when, on the 9th and 16th of the month, the nitrogen was very much below the usual amount; as again on December 4th. That such changes should take place is not at all surprising, although we may not be able to explain the reason why in each particular case. The water is taken from near the surface of the pond, flows in a conduit for some distance to the pumping-station, is pumped into an open reservoir, and thence distributed into the city. We know that the organic matter in natural water undergoes change with greater or less rapidity, owing to the difference of temperature, to the action of the wind, to the length of time during which the water is exposed to the sun and air in the reservoir, and to other such causes.

That the considerable variation in the amount and relative proportion of the organic carbon and organic nitrogen is not peculiar to Mystic water, may be seen from Table IV., compiled from the Sixth Report of the Rivers Pollution Commission, which shows the variation in the water of the several companies which supply the city of London, Eng. The same thing is true in other places as well.

TABLE IV. — *Variation in Monthly Samples of London Water, 1873.*

(Results expressed in parts in 100,000.)

Name of Company.	Organic Carbon.			Organic Nitrogen.		
	Maximum at any one time.	Minimum at any one time.	Mean of 12 Samples.	Maximum at any one time.	Minimum at any one time.	Mean of 12 Samples.
Chelsea	0.447	0.121	0.197	0.067	0.013	0.034
West Middlesex	0.341	0.114	0.173	0.055	0.015	0.028
Southwark	0.396	0.118	0.186	0.060	0.020	0.030
Grand Junction	0.412	0.117	0.183	0.050	0.016	0.032
Lambeth	0.449	0.130	0.206	0.065	0.021	0.040
New River	0.257	0.059	0.107	0.032	0.010	0.018
East London	0.333	0.109	0.175	0.082	0.015	0.035

In order to judge of the general character of the Mystic water, as shown by the results of Frankland's method of analysis, we have the necessary material in Table V., from which it appears that the total amount of organic matter, as indicated by the organic carbon and nitrogen, would be somewhat less than in Cochituate, were it not for the increase brought about by the development during the summer months of the *algæ*, to which allusion has been made. It

appears, however, that, on the whole, there is a *larger proportion* of nitrogen in the Mystic than in the Cochituate water; and this agrees with what we know of the character of the respective watersheds. Considering also that the total dissolved substances, organic and inorganic, amount to twice as much in the Mystic as in the Cochituate supply, we must regard the latter as the better water; the examination shows, however, as far as chemical examination can show, that, in spite of the polluting influences which have been at work in the ponds and streams supplying Mystic pond, the water, in its normal condition, is still good, and well suited for domestic supply.

There is one other point to which allusion might be made. In pursuit of some inquiries in which I have been engaged, I have had made a number of chemical examinations of the water of Mystic pond at the depth of eighteen feet, and also at the bottom of the pond. Since January we have been able, by having a buoy anchored in the pond, to take the samples at the same point where the water is seventy-five feet deep. Previous to that time we did not always succeed in finding the same spot, and some of the bottom samples were taken at a depth of fifty feet only. Being unable for the present to prosecute the research which I had planned, I should like to put the results thus far obtained on permanent record. They are included in tables VI. and VII.

Respectfully submitted,

WM. RIPLEY NICHOLS.

Massachusetts Institute of Technology, June, 1880.

TABLE V. — *Comparison of Mystic and other Waters.*

(Results expressed in parts in 100,000.)

Date.	Description.	Organic Carbon.	Organic Nitrogen.	Sum of the Organic Elements.	Ratio. Carbon / Nitrogen.
June, 1879—May, 1880	Mystic water as drawn in Charlestown. Mean of 39 samples	0.392	0.065	0.457	6.0
Sept. 18, 1879—May 27, 1880	Mystic water as above, — omitting the samples taken while the *algæ* were abundant. Mean of 28 samples	0.336	0.053	0.389	6.3
Jan., 1879—June, 1879	Boston water (Cochituate Lake and Sudbury River). Mean of 22 samples[1]	0.408	0.052	0.460	7.9
June, 1879—May, 1880	Boston water. Mean of 42 samples	0.452	0.051	0.503	8.9
Jan., 1879—June, 1879	Fresh Pond,[2] Cambridge. Mean of 11 samples	0.417	0.074	0.491	5.6
May, 1873—May, 1874	Loch Katrine water,[3] Glasgow, Scotland. Mean of 12 samples	0.197	0.018	0.215	10.9
	Unpolluted surface waters.[4] Mean of 195 samples	0.322	0.032	0.354	10.0

[1] Third Annual Report of Boston Water Board, 1879.
[2] These samples were taken from the pond itself, and the results do not claim to represent the water as delivered in Cambridge.
[3] Sixth Report of Rivers Pollution Commission, p. 347.
[4] Sixth Report of Rivers Pollution Commission, p. 425.

TABLE VI. — *Examination of Water in Mystic Lake.*

(Results expressed in parts in 100,000.)

Date.	Depth below Surface.	Ammonia.	"Albuminoid Ammonia."	Total Solids.
Oct. 18, 1879 . . .	18 feet	0.001	0.017	9.1
Nov. 8, 1879 . . .	"	0.008	0.011	9.6
Nov. 15, 1879 . .	"	0.008	0.013	9.6
Nov. 22, 1879 . .	"	0.015	0.013	9.8
Dec. 8, 1879 . . .	"	0.011	0.011	9.6
Jan. 30, 1880 . .	"	0.031	0.016	11.1
Feb. 6, 1880 . . .	"	0.035	0.019	11.1
Feb. 17, 1880 . .	"	0.041	0.016	10.8
March 6, 1880 . .	"	0.040	0.016	10.4
April 5, 1880 . .	"	0.040	0.013	10.2
April 14, 1880 . .	"	0.040	0.016	10.4
May 12, 1880 . .	"	0.032	0.016	10.5
May 24, 1880 . .	"	0.040	0.016	10.6
June 3, 1880 . . .	"	0.036	0.017	10.3
Average	. . . . .	0.027	0.015	10.2

TABLE VII. — *Examination of Water in Mystic Lake.*

(Results expressed in parts in 100,000.)

Date.	Depth below Surface.	Organic Carbon.	Organic Nitrogen.	Sum of Organic Elements.	Ammonia.	"Albuminoid Ammonia."	Total Solids.
Oct. 18, 1879 . . .	69 feet.	. . . .	. . . .	. . . .	0.007	0.011	7.8
Nov. 8, " . . .	50 "	0.307	0.047	0.354	0.009	0.011	9.6
Nov. 15, " . . .	60 "	0.606	0.106	0.712	0.023	0.027	11.6
Nov. 22, " . . .	50 "	0.309	0.047	0.356	0.016	0.017	9.6
Dec. 8, " . . .	54 "	0.288	0.041	0.329	0.011	0.008	9.7
Jan. 30, 1880 . . .	70–78 "	0.403	0.033	0.436	0.027	0.016	11.8
Feb. 6, " . . .	70–78 "	0.514	0.071	0.585	0.080	0.019	11.8
Feb. 17, " . . .	70–78 "	0.440	0.096	0.536	0.075	0.017	11.5
March 6, " . . .	70–78 "	0.312	0.032	0.344	0.040	0.015	9.5
April 5, " . . .	70–78 "	0.287	0.037	0.324	0.041	0.013	10.2
April 14, " . . .	70–78 "	0.295	0.086	0.381	0.043	0.017	10.3
May 3, " . . .	70–78 "	. . . .	. . . .	. . . .	0.048	0.019	10.1
May 12, " . . .	70–78 "	0.338	0.063	0.401	0.064	0.016	10.3
May 24, " . . .	70–78 "	0.363	0.083	0.446	0.064	0.015	10.5
June 3, " . . .	70–78 "	0.318	0.077	0.395	0.049	0.016	10.6
Average at bottom		0.368	0.063	0.431	0.040	0.016	10.3
Average at 18 ft. from top (Table VI.) .		. . . .	. . . .	. . . .	0.027	0.015	10.2
Average at top during the same time, Oct., '79—June, '80		0.349	0.054	0.403	0.028	0.018	10.0
Average as drawn in Charlestown during the same time		0.339	0.053	0.392	0.019	0.015	9.8